საერთაშორისო სამეცნიერო კონფერენცია „დედამიწასა და მის გარსებში მიმდინარე გეოფიზიკური პროცესები“
შრომები, ISBN 978-9941-36-147-0, თბილისი, საქართველო, 16-17 ნოემბერი, 2023 წ.
International Scientific Conference "Geophysical Processes in the Earth and its Envelopes"
Proceedings, ISBN 978-9941-36-147-0, Tbilisi, Georgia, November 16-17, 2023

SOME RESULTS OF STATISTICAL ANALYSIS OF THE DAILY WIND SPEED IN TBILISI IN 1971-2020

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Abstract: *Some results statistical analysis of the daily mean (W_{mean}) and max (W_{max}) wind speed for Tbilisi from January 1, 1971 to December 31, 2020 are presented. In 1971-2020 annual mean of W_{mean} was 1.5 m/sec, and W_{max} - 9.1 m/sec. In 1996-2020 compared with 1971-1995 annual mean of W_{mean} increased by 0.8 m/sec, and W_{max} - by 0.3 m/sec. Intraannual distribution of monthly average of daily mean and max wind speed Tbilisi in 1971-2020 has the form of a sixth power polynomial. Regression equations were obtained for the relationship between the repetition of mean daily and maximum wind speed in Tbilisi with the central points of wind speed on the Beaufort Wind Scale.*

Key Words: *Wind speed, Beaufort Wind Scale, statistical analysis.*

Introduction

As is known, the wind regime largely determines the climatic character of the area. Therefore, special attention is paid to the study of this climate-forming factor everywhere, including in Georgia [1-8]. Strong winds often destroy residential and industrial buildings, stop land and air transport, contribute to the appearance of blizzards, increase the negative consequences of other dangerous hydrometeorological phenomena (precipitation, hail, etc.), loss of life, etc. [6, 9-12]. Data on wind conditions are important for the development of wind energy, the agricultural sector of the economy, construction [1,8], etc. The level of air pollution and the formation of photochemical smog largely depend on wind speed [13]. Information about wind is important for the development of the resort and tourism industry by assessing various simple and complex bioclimatic indicators for specific territories [8,14,15].

This study is a continuation of work [7]. Below are some results of a statistical analysis of the average daily and maximum wind speed for Tbilisi from January 1, 1971 to December 31, 2020.

Study area, material and methods

Study area – Tbilisi. The data of Georgian National Environmental Agency about the daily mean and max wind speed for Tbilisi from January 1, 1971 to December 31, 2020 (18263 days) are used. Coordinates of meteorological station in Vashlijvari: Lat - 41.75785° N, Long - 44.755184° E, Elevation – 427 m a.s.l.

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods [16]. The following designations will be used below: Mean – average values; Max - maximal values; Min – minimal values; St Dev - standard deviation; σm - standard error; Cv – coefficient of variation = 100·St Dev/Mean, %; R^2 - coefficient of determination; R – coefficient of linear correlation; 95%(+/-) and 99%(+/-) - 95% and 99% confidence interval of the mean; W_{mean} - mean wind speed (m/sec); W_{max} - max wind speed.

Wind speed repeatability was determined in accordance with the Beaufort Wind Scale (Table 1).

Appearance of Wind Effects on Land in https://www.spc.noaa.gov/faq/tornado/beaufort.html; https://www.ka-kras.ru/interesn/wind.htm and [7] are presented.

Table 1. Beaufort Wind Scale [https://www.spc.noaa.gov/faq/tornado/beaufort.html; https://www.kakras.ru/interesn/wind.htm].

Force	Central point of wind speed, (CPWS, m/sec)	WMO Classification	Force	Central point of wind speed, (CPWS, m/sec)	WMO Classification
0	0.1	Calm	7	15.5	Near Gale
1	0.9	Light Air	8	18.95	Gale
2	2.45	Light Breeze	9	22.6	Strong Gale
3	4.4	Gentle Breeze	10	26.45	Storm
4	6.7	Moderate	11	30.55	Violent Storm
5	9.35	Fresh Breeze	12	>32.6	Hurricane
6	12.3	Strong Breeze			

Results and discussion

Results in Table 2-5 and Fig. 1,2 are presented.

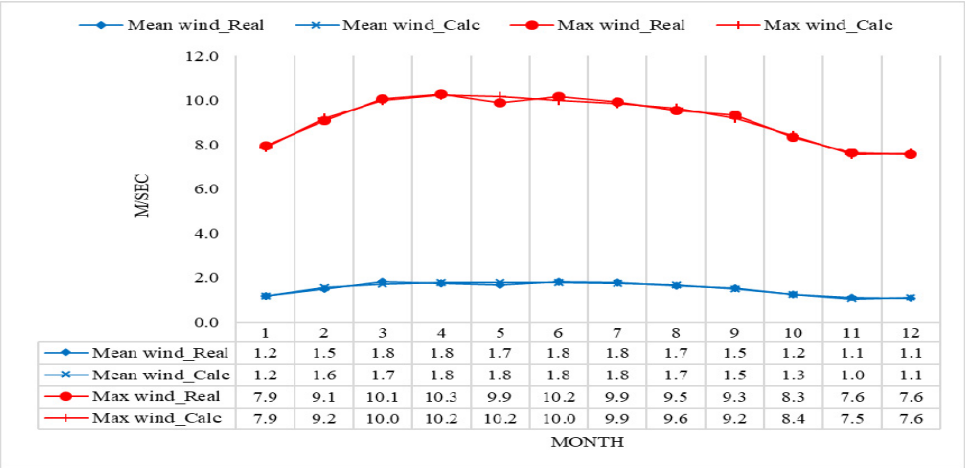
In Table 2 statistical characteristics of W_{mean} and W_{max} in Tbilisi in 1971-2016, 1971-1995 and 1996-2020 are presented.

Table 2. Statistical characteristics of daily mean and max wind speed (m/sec) in Tbilisi in 1971-2016, 1971-1995 and 1996-2020 (min wind speed = 0).

Period	1971-2020		1971-1995		1996-2020	
Variable	W_{mean}	W_{max}	W_{mean}	W_{max}	W_{mean}	W_{max}
Mean	1.5	9.1	1.1	9.0	1.9	9.3
Max	14.9	41.0	14.9	41.0	12.0	32.0
St Dev	1.5	4.6	1.3	4.6	1.5	4.6
σm	0.01	0.03	0.01	0.05	0.02	0.05
Cv, (%)	97.4	50.4	117.8	51.8	79.8	49.1
95%(+/-)	0.02	0.07	0.03	0.10	0.03	0.09
99%(+/-)	0.03	0.09	0.04	0.13	0.04	0.12
R	0.75		0.75		0.79	
Linear Regression	$W_{max} = a \cdot W_{mean} + b$					
Linear Regression Equation Coefficients	a	b	a	b	a	b
	2.36	5.57	2.61	5.99	2.40	4.80

In particular, as follows from Table 2, in 1971-2020 annual mean of W_{mean} was 1.5 m/sec, and W_{max} - 9.1 m/sec. In 1996-2020 compared with 1971-1995 annual mean of W_{mean} increased by 0.8 m/sec, and W_{max} - by 0.3 m/sec. Coefficient of linear correlation between W_{mean} and W_{max} change from 0.75 (1971-2020, 1971-1995) to 0.79 (1996-2020) - high correlation.

In Fig. 1 real and calculated data on intraannual distribution of monthly average of daily mean and max wind speed in Tbilisi in 1971-2020 are presented.



	1	2	3	4	5	6	7	8	9	10	11	12
Mean wind_Real	1.2	1.5	1.8	1.8	1.7	1.8	1.8	1.7	1.5	1.2	1.1	1.1
Mean wind_Calc	1.2	1.6	1.7	1.8	1.8	1.8	1.8	1.7	1.5	1.3	1.0	1.1
Max wind_Real	7.9	9.1	10.1	10.3	9.9	10.2	9.9	9.5	9.3	8.3	7.6	7.6
Max wind_Calc	7.9	9.2	10.0	10.2	10.2	10.0	9.9	9.6	9.2	8.4	7.5	7.6

Fig. 1. Intraannual distribution of monthly average of daily mean and max wind speed Tbilisi in 1971-2020 (Real and Calc).

Table 3. Regression equation coefficients for intra-annual distribution of monthly average of daily mean and max wind speed Tbilisi in 1971-2020

Regression Equation	$Y = a \cdot X^6+b \cdot X^5+c \cdot X^4+d \cdot X^3+e \cdot X^2+f \cdot X+g$, X - months							
Coefficient	a	b	c	d	e	f	g	R^2
W_{mean}	0.00001225	-0.00026	0.000236	0.029231	-0.27239	0.996083	0.431818	0.971
W_{max}	0.000141612	-0.00495	0.064455	-0.3755	0.78389	0.767397	6.643939	0.984

These distributions have the form of a sixth power polynomial. The corresponding regression equation coefficients are presented in Table 3.

In Table 4 data about repetition of daily mean and max wind speed in Tbilisi according to Beaufort Wind Scale are presented.

Table 4. Repetition of daily mean and max wind speed in Tbilisi according to Beaufort Wind Scale (BWS).

BWS	0	1	2	3	4	5	6	7	8	9	10	11	12
CPWS, m/sec	0.1	0.9	2.5	4.4	6.7	9.4	12.3	15.5	19.0	22.6	26.5	30.6	32.6
W_{mean}	17.9	44.5	26.2	9.1	2.2	0.15	0.02	0.01					
W_{max}	1.3	0.36	4.3	15.6	30.9	18.9	15.7	6.7	4.7	1.1	0.25	0.10	0.02

As follows from Table 4 W_{mean} values cover the Beaufort scale from 0 to 7, while W_{max} covers the entire scale. The maximum repeatability of W_{mean} n values falls on number 1 of the Beaufort scale (44.5%, smoke drift indicates wind direction, still wind vanes), and W_{max} - on number 4 of this scale (30.9 %, dust, leaves, and loose paper lifted, small tree branches move). The scale range of 8 and more (≥17.2 m/sec, gale and above, the onset of destructive processes in the environment and their intensification) accounts for about 6.2% of cases (about 23 days a year). During the entire period of research with hurricane wind as in [7] 3 cases were recorded (Beaufort scale range - 12, hurricane, wind speed >32.6 m/sec, devastating destruction).

In Table 5 corresponding regression equation coefficients for repetition of daily mean and max wind speed in Tbilisi according to central points of wind speed of number of Beaufort Wind Scale Force in 1971-2020 are presented.

Table 5. Regression equation coefficients for repetition of daily mean and max wind speed in Tbilisi according to central points of wind speed of Beaufort Wind Scale **Force** in 1971-2020. X, m/sec.

Variable	W_{mean}				W_{max}			
Regression Equation	$Y = a \cdot X^b \cdot \exp(-c \cdot X)$				$Y = \exp(a+b/X+c \cdot \log(X))$			
Coefficient	a	b	c	R^2	a	b	c	R^2
	96.110491	0.69383	0.778674	1	18.5126	-	-5.21855	0.962

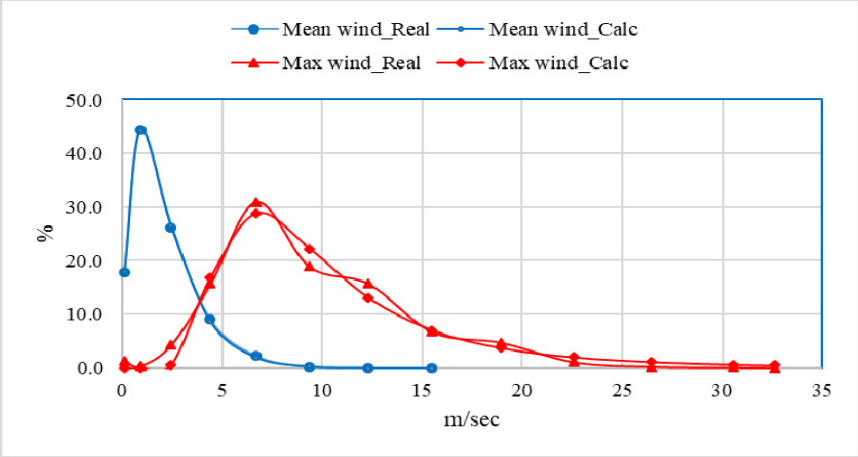


Fig. 2. Repetition of daily mean and max wind speed in Tbilisi (Real and Calc) according to central points of wind speed of Beaufort Wind Scale ***Force*** *in 1971-2020.*

In Fig. 2 for clarity curves of repetition of real and calculated daily mean and max wind speed in Tbilisi according to central points of wind speed of Beaufort Wind Scale Force in 1971-2020 are shown.

As follows from Table 4 and Fig. 2 real and calculated repeatability curves for average wind speed practically coincide ($R^2 = 1$). The degree of agreement between real and calculated repeatability curves for max wind speed is somewhat worse, although quite high ($R^2 = 0.962$).

Conclusion

In the future, we plan to continue similar studies both for Tbilisi and other regions of Georgia, taking into account climate change. In particular, in the near future it is planned to conduct research on the variability of wind speed in Tbilisi in various months of the year over the past 60 years.

Acknowledgement

The research is done with the support of "Shota Rustaveli National Scientist Foundation" [Grant number - FR-22-2882].

The authors are grateful to the chief of the atmospheric physics department of M. Nodia Institute of Geophysics A. Amiranashvili for assistance in the fulfillment of this work.

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